10/581860
IAP2 Rec'd PCT/PTO 05 JUN 2006

Method for Reducing the Noise of Turbo Engines

The invention relates to a method for reducing the noise of turbo engines according to the preamble of claim 1 as well as a rotor-stator arrangement according to claim 10.

Turbo engines are characterized by a sequential arrangement of rotating and stationary cascades, also referred to as the rotor and stator. Fig. 1 shows by way of example the arrangement of the rotor and stator in an aircraft engine. The working medium, typically air, passes in the direction of the arrow the combination of rotors and stators in the different modules a, b, c of the turbo engine. In Fig. 1 reference letter a designates the fan section, which is produced in the direction of flow from the combination of the fan R1 and the guide vane S1 in the primary circuit 1 and/or the outlet guide vane S2 in the secondary circuit 2. The compressor stage b in the direction of flow is the combination of the impeller R3 and the guide vane S3 and the turbine stage c in the direction of flow is the combination of the guide vane S4 and the impeller R4.

Other turbo engines are known, for example, as compressors, fans, or power plant turbines.

One of the primary noise sources of this arrangement is the rotor-stator interaction stator-rotor interaction. The rotor-stator interaction noise is the product of the following mechanism: Due to the periodic peripheral wake of a rotating cascade (rotor), a downstream stationary cascade (stator) is exposed to period transient flow, causing periodic hydrodynamic pressure fluctuations to be applied to these stator blades, which are emitted to the surrounding area as tonal noise.

The rotor-stator interaction noise is the product of the following mechanism: When a rotating cascade (rotor) penetrates the stationary wake of an upstream stationary cascade (stator), the rotor blades are subjected to periodic transient flow, causing periodic pressure fluctuations on these rotor blades, which are emitted to the surrounding area as tonal noise.

During take-off and landing, the afore-mentioned mechanisms contribute considerably to the noise emission of commercial airplanes and therefore represent a restrictive variable with respect to the ever more stringent noise protection regulations of airports and their surrounding areas.

We know of active and passive noise attenuation systems. For example, acoustic liners are installed in the delimiting areas of the flow ducts of the engine, or the rotor-stator spacing is increased. US 4,313,387 disclosed a passive system, where reduced noise is achieved by curving the stator blades. One disadvantage of these measures is that the size and the weight of the engine increase.

Another passive measure, where the rotor comprises a serrated shape at the rear edge, is revealed in EP 1 277 966.

US 5,335,417 and US 5,420,383 disclose active measures for noise reduction, according to which acoustic sources are disposed in the inlet of the engine and/or secondary duct of a turbo engine and/or in the stator blade. These measures are based on the anti-noise principle. To this end, by means of a complex distribution of acoustic sources, the attempt is made to imitate the modular characteristic nature of the sound field. A disadvantage is that these methods and systems are very complex.

Additionally, US 6,004,095 disclosed a method for achieving noise reduction by continuously blowing the rotor trailing edge.

It is the object of the invention to provide a method, which improves the reduction of noise emission in turbo engines by means of active measures. Another object relates to the provision of a rotor-stator arrangement, which allows the implementation of noise reduction in turbo engines.

These objects are achieved with the method according to the characteristics of claim 1 as well as the rotor-stator arrangement according to the characteristics of claim 9. Advantageous embodiments of the invention are the object of the dependent claims.

According to the invention, the hydrodynamic pressure fluctuations occurring on the cascades are lowered by varying the surface circulation of at least one section of at least one stator. Unlike the familiar methods, this method directly approaches the source where the noise is produced.

In an advantageous embodiment of the invention, the surface circulation of one or more blades of the stator is varied. To this end, it is particularly advantageous that the aerodynamic characteristics of the stator are influenced by the deflection of one or more blades of the stator or sections of the blades. Of course it is conceivable to influence the aerodynamics of any arbitrary number of stators present in a turbo engine with the method according to the invention.

In particular it is advantageously possible to vary the surface circulation of the stator periodically. Furthermore, according to another advantageous embodiment of the invention, the control of the individual stator blades of a cascade can be performed either individually or corresponding to the separation and the rotational speed of the rotor with a delay. The control frequency of periodic processes advantageously corresponds to the base frequency of the tonal noise and

is obtained from the product of the rotor blade number and the rotational speed. The phase position and/or the amplitude of the control are advantageously controlled corresponding to suitable error signals. These error signals are supplied in particular from microphones or pressure sensors.

The method according to the invention therefore makes it possible to adjust the surface circulation of the stator blades such that the pressure fluctuations produced by the peripheral wake of an upstream rotating cascade on these stator blades are reduced or that the pressure fluctuations produced by the wake these stator blades on a downstream rotating cascade are reduced.Of course it is possible in the case of a multi-stage configuration of a turbo engine to employ a combination of the effects described above.

The rotor-stator arrangement according to the invention comprises one or more stator means for influencing the aerodynamics of the stator. The means advantageously are:

- one or more blades of the stator, which blades are movable about a predefined axis,
- one or more movable leading edge flaps, which are disposed on one or more blades of the stator,
- one or more movable trailing edge flaps, which are disposed on one or more blades of the stator,
- one or more movable surface elements, which are disposed on one or more blades of the stator.

Additionally, one or more openings for the suction and/or blowing of air are provided on the surface of one or more blades of the stator. This way it is also possible to influence the occurring pressure fluctuations. Particularly when performing period blowing and/or suction steps on the surface of the stator blades, it

is possible to reduce the pressure fluctuations produced by the peripheral wake of an upstream rotating cascade.

In another advantageous embodiment of the inventive rotor-stator arrangement, one or more openings for blowing air are provided on the trailing edge of one or more blades of a stator. In a suitable configuration, continuous blowing of air on the trailing edge of the stator blades harmonizes the circulation of a downstream rotating cascade, thus lowering the resultant pressure fluctuations.

Advantageously, the means for influencing the aerodynamics of a stator are mechanically, electrically, piezo-electrically or pneumatically operated actuators. Of course it is possible, depending on the application and position of an actuator in the rotor-stator arrangement, to use different actuators. Contrary to the actuators used in the familiar methods or devices attenuating noise in turbo engines, the actuators used in the method according to the invention and the rotor-stator arrangement according to the invention do not serve the generation of an anti-noise field, which compensates the sound field produced by the turbo engine. According to the invention, the actuators serve the deflection of the stator or sections of the stator, particularly of the blades or sections of the blades.

An active system corresponding to the present invention can be suitably combined with passive systems. This way it is possible, for example, to activate the system according to the invention in addition to potentially present passive systems in airplane engines during the noise-relevant flight phases (take-off and landing).

The system according to the invention can of course also be used in turbo engines not used in the aeronautics industry, for example in power plant turbines.

One advantage of the invention is that the system is maintenance- and

assembly-friendly since the actuators are provided in the stationary system of the stators.

The invention will be explained in more detail with references to the drawing, wherein:

Fig. 1 is an example of an engine in a sectional view,

Fig. 2 is an example of the blades of a stator with the means according to the invention for varying the aerodynamics of the stator,

Fig. 3 are examples of the blades of a stator with openings for the suction and blowing of air.

Fig. 2 shows by way of example the blades of a stator with the means according to the invention for varying the aerodynamics of the stator. Reference numeral 11 here designates any arbitrary axis, about which the blade S is movably disposed. A blade S can be provided with leading edge flaps 12 and/or trailing edge flaps 13. Beyond that, a blade S may comprise one or more means 14, which are disposed on the surface of the blade S. These means 14 can be actuators, for example.

Fig. 3 shows in the upper part an illustration by way of example of a blade S, which comprises openings 15 and 16 in the area of the leading edge and in the center area. These openings 15 and 16 can serve on one hand the suction of air or on the other hand the blowing of air. The lower part of Fig. 3 shows by way of example a blade S, which comprises an opening 17 in the area of the trailing edge, which opening allows air to be blown out continuously. Of course the means 15, 16, 17 for the suction and blowing of air can be mutually combined arbitrarily. It can be provided, for example, also that adjoining blades of a stator comprise openings for the suction or blowing of air, which openings are disposed in different configurations.